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DETERMINATION OF STUDENT QUOTAS
FOR THE
MARINE CORPS SPECIAL EDUCATION PROGRAM

by

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and
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DETERMINATION OF STUDENT QUOTAS FOR THE MARINE CORPS SPECIAL EDUCATION PROGRAM

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ABSTRACT

This thesis presents and evaluates five manpower models which can be used to determine quotas for the U. S. Marine Corps Special Education Program. Both static and dynamic modelling techniques are used. Each model is based on a network concept which depicts the manpower flows through the Special Education Program. The quotas provided by each of the five models are compared on the basis of twenty-year average projections and on the basis of Fiscal Year 1978 projections. Sample APL functions for one of the models is presented in an appendix.

TABLE OF CONTENTS

I. STATEMENT OF THE PROBLEM

How to determine graduate school quotas for the Marine Corps Special Education Program.

II. INTRODUCTION

Five models are presented and evaluated for use in determining graduate school quotas for the U. S. Marine Corps Special Education Program (SEP). The steady state, basic transient, and smoothed transient models were originally developed for use by the U. S. Navy. These models are adapted, herein, for use by the U.S. Marine Corps. The career path steady state and career path transient models are developed specifically for modelling SEP quota requirements. After each model is described and discussed separately, the quota projections of the models are compared, and conclusions are presented.

Of the twenty-three SEP Military Occupational Specialties (MOS), five were selected for use in the analysis. Three of the five (SEP MOS's 9644, 9646, and 9650) are representative of MOS's with relatively large billet requirements and differing billet structures (e.g. 33 percent of the 9644 billets are in the rank of colonel; whereas only 2 percent are colonel billets in the 9650 MOS.). MOS 9620 was selected as representative of those SEP MOS's with medium sized billet requirements. MOS 9624 was included because it was of particular interest to the SEp monitor at Headquarters, U.S. Marine Corps.

III. BACKGROUND INFORMATION

Throughout the Marine Corps there is a total of 447 billets which require assignment of an officer holding a SEP MOS. These billets require skills normally associated with graduate level education. Each billet has been established by a rigorous validation process which carefully assesses the necessity and justification for the existence of each billet. A list of the billets by rank for the MOS's 9620, 9624, 9644, 9646, and 9650 is provided in Appendix A.

The Special Education Program is the primary source for obtaining graduate educated officers to meet future SEP billet requirements. Other sources are the Advanced Degree Program and officers who have earned graduate degrees either before entering the Marine Corps or after commissioning through off-duty education.

Each year the Marine Corps selects a certain number of officers for the necessary graduate education at the Naval Postgraduate School and certain civilian universities. According to Reference 1, officers within the ranks of first lieutenant through lieutenant colonel are eligible to apply for SEP. Those officers wishinq consideration must submit a formal letter of application in which they are required to state their preference for three SEP disciplines. Officers are selected on the basis of their service and academic records, and are normally ordered to school within the next fiscal year. Upon completion of degree requirements, the officer is assigned the appropriate SEP MOS and is eligible for assignment to a SEP billet. Current Marine Corps policy calls for immediate utilization in a SEP tour of each

officer upon graduation with the exception of an officer being due for a one-year unaccompanied overseas tour. The officer who is due for an overseas tour would serve in a SEP billet immediately upon completion of the overseas tour. Thereafter, an officer will usually serve in a SEP billet every other tour of duty.

Currently, SEP quotas are determined by using a "2.4 factor" and by other considerations. Reference 2 provides information on the derivation of the 2.4 factor. Basically, the concept is that the number of SEP trained officers with a specific SEP MOS should be 2.4 times as large as the number of billets for that MOS. The 2.4 factor is applied to both the total number of billets in a SEP MOS and the number of billets by rank within a MOS. For example, if there are a total of ten billets for a MOS with five billets each in the ranks of captain and major, then there should be a total of 24 officers trained of whom 12 are captains and 12 are majors. When the officer inventory, either by gross total or total by rank, is below the amount determined by using the 2.4 factor, the deficit is the number of officers who ought to be sent to school in a certain year.

The "raw" quota given by the 2.4 factor is amended by the following considerations. Future SEP billet vacancies are forecasted by estimating tour rotations of officers currently in the inventory and by estimating likely attrition (a flat 10 percent attrition rate is used). Promotion possibilities and budgetary constraints are also considered. Finally, the amended quota is modified, when appropriate, to an amount no larger than one third of the billets for a MOS since it is expected that only one third of the billets will become vacant per year on the average. This last modification is made to assure that all officers can be immediately utilized in a SEP tour after graduation from school.

IV. STEADY STATE MODEL

A. MODEL DESIGN

1. General Description

The steady state model developed in Reference 3 equates input and output rates to determine flows through officer billets. Average annual billet requirements by rank within each SEP MOS are calculated. The annual billet requirements (outflow rates) can be met from two inflow sources. One source is those SEP trained officers previously eligible to serve in a lower rank SEP billet who are now eligible and available to serve in a billet of the rank being considered. When this source fails to provide sufficient manpower to meet billet needs, additional graduate educated officers must be obtained. Those officers who enter school comprise the second source.

2. Assumptions

The following assumptions are implicit in the steady state model.

1. Flow rates into and out of billets remain constant.

2. Annual billet requirements remain constant.

3. Annual student input is available to meet the determined quota.

Additionally, to adapt this model for Marine Corps use the following assumptions were made.

4. Tour lengths in all SEP billets are the same. With the exception of a small number of SEP billets in the Fleet Marine Force, Pacific, which are filled by officers serving a one-year unaccompanied overseas tour, it has been Marine Corps policy that the billet tour length is three years.

5. All officers entering graduate education to meet a billet requirement in a particular SEP MOS and rank will serve in a SEP billet immediately after graduation. An exception is those officers who incur a one year delay before filling a billet by reason of serving an unaccompanied overseas tour. This one year delay does not affect the manpower flow through the steady state model provided that the proportion of graduates going overseas remains constant.

6. Graduate educated officers will serve in a SEP billet at every opportunity. That is, they will serve a three year SEP tour once during each rank held where a billet requirement exists.

7. No attrition occurs between the rank of first lieutenant and the rank of captain.

3. Notation

Subscript i on the variables indicate rank as follows--

Subscript	Rank
3	Capt
4	Maj
5	LtCol
6	Col

B_i is the number of SEP billets in rank i for a particular SEP MOS. T_i is the tour length in these billets. The average annual billet requirement is equal to B_i/T_i. For example, with $T_i = 3$ it can be expected in a steady state flow that one third of the officers in SEP billets are in the first, second, and third year respectively of their tour. Hence, one third of the billets will become vacant each year.

X_i is the input per year into graduate education in order to meet the future billet requirements in rank i for some particular SEP MOS.

Three parameters affect the magnitude of the flow of officers through the model: a_i is the fraction of officers who enter graduate school to meet a future billet requirement in rank i, and who are still in the service and eligible to meet that requirement; b_i is the fraction of those available to serve a SEP tour in rank i who actually

serve such a tour; c_i is the fraction of officers eligible to serve in a SEP billet in rank i who are available to serve a SEP tour in rank i+1.

4. Formulation

On the basis of assumptions 5 and 6, a_i and b_i are equal to 1 for the Marine Corps. Hence, the steady state model was simplified for Marine Corps use. For a given SEP MOS, the annual student quota into graduate school to meet captain billet requirements is

$$X_3 = B_3/T_3.$$

The major billet requirement, B_4/T_4, can be met from two sources. The primary source is those officers previously trained to meet captain billet requirements who are now eligible and available to serve in a major's billet. c_3X_3 is the number of officers from this source. If $c_3X_3 \geq B_4/T_4$, then no new input into graduate education is necessary for major billet requirements. If, however, $c_3X_3 < B_4/T_4$, then X_4 officers must be trained to make up the difference between c_3X_3 and B_4/T_4. expressing the major billet requirements in terms of the two sources gives

$$B_4/T_4 = c_3X_3 + X_4$$

when $c_3X_3 < B_4/T_4$. And $X_4 = 0$ when $c_3X_3 \geq B_4/T_4$. Since all

$X_i \geq 0$, the X_4 quota is found by simple algebraic manipulation to be

$$X_4 = \text{Max}[0,\ B_4/T_4 - c_3X_3].$$

Similar arguments show that

$$X_5 = \text{Max}[0,\ B_5/T_5 - (c_4X_4 + c_3c_4X_3)],$$

$$X_6 = \text{Max}[0,\ B_6/T_6 - (c_5X_5 + c_4c_5X_4 + c_3c_4c_5X_3)].$$

The total graduate education quota needed each year is $X_3 + X_4 + X_5 + X_6$ for a particular SEP MOS.

B. MODEL APPLICATIONS

Reference 3 provides a computer program in APL (A Programming Language) for the steady state model.

Continuation fractions (c_i) were based on the data in Appendix B. The a_i and b_i parameters were set at 1 (assumptions 5 and 6).

Figure 1. provides projections for SEP MOS 9650 using current Marine Corps policy as the basis for setting parameter values. For the base case, the value of c_3 was set at 1 (assumption 7). The other c_i's were obtained by taking the cumulative product of the continuation rates

applicable to each rank i (where i = 4,5, and 6). All t_i were set at three years.

An example of modelling the impact of a change in SEP policy--changing tour lengths from three to four years-- is shown below for SEP MOS 9650:

$\underline{X}_3$	$\underline{X}_4$	$\underline{X}_5$	$\underline{X}_6$
3	5	0	0.

C. SENSITIVITY ANALYSIS

The lower bound for SEP MOS 9650 quota projections is furnished below:

$\underline{X}_3$	$\underline{X}_4$	$\underline{X}_5$	$\underline{X}_6$
4	5	0	0.

T_i was set at three years for all i. Lower bounds were found by setting all a_i, b_i and c_i equal to 1. This is the quota for a perfect system with no attrition. Realistically this bound would never be sufficient to meet SEP billet requirements. But, the bound does indicate a lower limit for the quotas below which manpower requirements for SEP billets cannot be met even under ideal conditions.

Without the assumption that a_i and b_i both equal 1 for all i, the formulation of the steady state model, as given by reference 3, is:

$$X_3 = 1/a_3 b_3 (B_3/T_3),$$

$$X_4 = 1/a_4 b_4 \ \mathrm{Max}[0,\ B_4/T_4 - a_3 c_3 X_3],$$

$$X_5 = 1/a_5 b_5 \ \mathrm{Max}[0,\ B_5/T_5 - (a_3 c_3 c_4 X_3 + a_4 c_4 X_4)],$$

$$X_6 = 1/a_6 b_6 \ \mathrm{Max}[0,\ B_6/T_6 - (a_3 c_3 c_4 c_5 X_3 + a_4 c_4 c_5 X_4 + a_5 c_5 X_5)].$$

by varying each parameter one at a time.

The sensitivity analysis was conducted Initial values were set as in the base case (see Figure 1 for the base case quota projections).

For a_i at a 0.05 error of estimation (i.e. $a_i = 0.95$ for all i) SEP MOS 9650 required an annual quota increase of 1 officer. For an error estimation of 0.1, no further change to the quotas occurred. The same quota changes occurred for 0.05 and 0.1 estimation errors of b_i.

c_i was evaluated for both over and under estimation of the true c_i by 0.05 and 0.1. An over estimation of c_i means that actual attrition is under estimated. The opposite applies for an under estimation of c_i. The results for SEP MOS 9650 are shown in Figure 2.

Rank i	Billets B_i	Tour Length T_i	a_i	b_i	c_i	Quota X_i
3	13	3	1	1	1.00	4
4	28	3	1	1	.60	7
5	17	3	1	1	.65	
6	1	3	1	1	.40	

Figure 1. Projected Steady State Quotas for MOS 9650.

Quota X_i	Lower Bound	Changes in c_i +0.10	+0.05	0.00	-0.05	-0.10
X_3	4	4	4	4	4	4
X_4	5	6	7	7	7	7
X_5					1	1
X_6						

Figure 2. Sensativity Analysis on Steady State Model Parameter, c_i, for MOS 9650.

V. BASIC TRANSIENT AND SMOOTHED TRANSIENT MODELS

A. MODEL DESIGN

1. General Description

Both models start at an initial period with a known personnel inventory of graduate educated officers. The inventory is categorized by SEP MOS; moreover within each MOS the inventory is further categorized by the number of officers in each year of service from one to thirty years. In succeeding periods the inventory will be subject to various attrition rates applicable to each year group. For example, only some fraction of the officers who have twenty years of service will continue on to complete twenty-one years of service. In the next period, out of those who remained for twenty-one years, not all will remain to serve twenty-two years. Although the inventory will be depleted by attrition, it will also be augmented in each period by officers who have completed their graduate training in the preceding period.

The transient models recognize that officers selected to meet a quota for school in a certain year will not be available to serve in a SEP tour until some later year. Thus, a quota determination for a planning year must be based on the needs in a future year when the officers have completed their graduate education and are available to serve a SEP tour. Those officers who remain in the

inventory, plus student additions, in a particular future period constitute the manpower assets in the personnel flow who can meet this future period's billet requirements. If these manpower assets are insufficient to meet billet requirements, then the difference determines the quota for the planning year. The output of the basic transient model tends to be cyclical over time in many cases. This cyclical effect occurs because the inventory is rarely uniformly distributed over the years of service categories. The size of a group of officers in a MOS with the same years of service may be relatively large (or small) compared to other groups which are a few more years senior or years junior. As this disproportionately sized group flows through the SEP billet structure, it will decrease (or increase) significantly the quota determination for a particular rank compared to quotas for the preceding and succeeding periods. Accordingly, a disproportionate number of officers enter school, and then later enter the inventory to meet the requirements of a certain rank. The cyclical nature of the quota is thus perpetuated.

The smoothed transient model is a modification of the basic transient model that reduces the fluctuations in the quota. The smoothed transient model makes an additional calculation of the quota by considering the average annual billet requirements as was done in the steady state model. The number of officers who will be entering the first year of a SEP tour in a certain rank are subtracted from the annual average billet requirement. If this amount is larger than both zero <u>and</u> the quota as determined by the basic transient algorithm, then the smoothed transient amount is used. In the long run the inventory and the quotas will approximate the steady state values; thereby, a reasonably stable student input requirement will be obtained from year to year.

2. Assumptions

The following assumptions are implicit in the basic transient and smoothed transient models.

1. All graduate trained officers will serve a three year SEP tour during each rank held.

2. The billets in each rank are filled by officers having certain years of service.

3. Attrition is directly related to years of service.

4. Continuation rates apply to both the inventory and students.

5. Adequate student input is available to meet quotas.

Additionally, to adapt these models for Marine Corps use, the following assumptions were made.

6. No attrition occurs between the ranks of first lieutenant and captain.

7. Officers will not leave the service either while attending graduate school or while serving an initial SEP tour.

3. Notation

For a fixed SEP MOS the inventory for that MOS is

given by $I_k(t)$ where k is the years of service (k = 1,2,3,...,30) and t is the period (t = 0,1,2,3,...); $t = 0$ is the current period. C_k is the fraction of those officers with k years of service who remain to have $(k+1)$ years of service. The "legacy" of past inventories is defined as the fraction of those officers in the preceding year's inventory with k years of service who remain in the inventory and now have $(k+1)$ years of service. $I'_k(t)$ will denote the legacy.

$S_k(t)$ are students from an earlier period who will enter the inventory in period t with k years of service.

The delay between selection for graduate school and entry into an initial SEP tour is represented by d. l_i and u_i are the lower and upper limits on years of service, respectively, for serving in a SEP billet in rank i (where i = 3,4,5,6). B_i is the number of SEP billets in rank i for a particular SEP MOS.

$Q_i(t)$ is the school quota in period t for rank i. This quota will be available to serve their first SEP tour in period $(t+d)$.

Finally, w_i is the tour length in rank i billets, and w_i is also equal to $u_i - l_i + 1$.

4. <u>Formulation</u>

The following formulation is applicable to both models.

In the current period the inventory for each SEP MOS is given. That is, for $t = 0$, $I_k(0)$ is those officers already SEP trained plus those students who will enter the inventory before $t = 1$. The next period's inventory (i.e. $t = 1$) is comprised of those officers who were in the inventory at $t = 0$ and remain in the inventory at $t = 1$, and those students who graduate and enter the inventory at $t = 1$. The inventory for period 1 is formulated as:

$$I_{k+1}(1) = C_k I_k(0) + S_{k+1}(1).$$

Similar logic applied to any planning year t shows that the future inventory in any period may be expressed as:

$$I_{k+1}(t+1) = C_k I_k(t) + S_{k+1}(t+1).$$

Since the transient model recognizes that officers selected for school in year t will not complete school and be available for a SEP tour until (t+d), quota determinations for year t are based on the needs of year (t+d). In period (t+d), for rank i in a particular SEP MOS, there are B_i billet requirements. On the basis of assumption 2 these billet requirements will be met by officers with $l_i, l_i+1, \ldots, u_i$ years of service. Furthermore, the officers in the inventory available to meet the billet requirements are the legacy from the preceding

period. The legacy may be expressed as $I'_{k+1}(t+1) = c_k I_k(t)$. The legacy for period (t+d) may be expressed as:

$$I'_k(t+d) = C_{k-1} I_{k-1}(t+d-1).$$

Thus, the total inventory legacy in rank i available to meet billet requirement B_i is:

$$I'_{l_i}(t+d) + I'_{l_i+1}(t+d) + \ldots + I'_{u_i}(t+d)$$

or, restated:

$$\text{total inventory in rank } i = \sum_{k=l_i}^{u_i} I'_k(t+d)$$

for period (t+d).

If the total inventory in rank i is greater than or equal to B_i, then the inventory provides sufficient manpower to meet the billet requirement--no student input is needed. If the total inventory in rank i is less than B_i, then $S_k(t+d)$ students are needed. $S_k(t+d)$ may be expressed as:

$$S_k(t+d) = B_i - \sum_{k=l_i}^{u_i} I'_k(t+d)$$

when the total inventory in rank i with years of service equivalent to l_i through u_i is less than B_i. Restating the foregoing:

$$S_k(t+d) = \mathrm{Max}[0,\ B_i - \sum_{k=l_i}^{u_i} I'_k(t+d)].$$

Because of assumption 4, the additions to the inventory in period (t+d) (i.e. $S_k(t+d)$) will be some

fraction of the student input (i.e. $Q_i(t)$) of period t. Expressed algebraically:

$$(c_{l_i-d})(c_{l_i-d+1})(\ldots)(c_{l_i-1})Q_i(t) = S_k(t+d).$$

Therefore, the quota in planning year t to meet the billet requirements in year (t+d) for rank i in a particular SEP MOS is:

$$Q_i(t) = S_k(t+d) / \prod_{k=l_i-d}^{l_i-1} c_k.$$

For the smoothed transient model the calculation of $S_k(t+d)$ is modified. Annual average billet requirements for rank i in a particular SEP MOS are given by B_i/w_i. The smoothing effect is accomplished by letting

$$S_k(t+d) = \mathrm{Max}[0, (B_i - \sum_{j=l_i-d}^{l_i-1} I'_j(t+d)), (B_i/w_i - I'_k(t+d))]$$

for each $k = l_3, l_4, l_5, l_6$.

The total graduate education quota provided by either of the two models is $Q_3(t) + Q_4(t) + Q_5(t) + Q_6(t)$ for a SEP MOS.

B. MODEL APPLICATIONS

Reference 3 provides computer programs in APL for the basic transient and smoothed transient models.

Billet tour lengths were set at three years; the delay

(d) was set at two years. Continuation fractions were based on the data in Appendix B. l_i and u_i were set as follows:

i	l_i	u_i
3	7	9
4	13	15
5	19	21
6	25	27.

Figure 3 shows the quota projections for SEP MOS 9650 using the basic transient model. This quota is the "base case" quota where the values of all parameters were set to model present Marine Corps SEP policy. Figure 4 shows the 9650 personnel inventory and student inventory, along with other information, for the base case. Cumulative total continuation rates were calculated for each rank with the cumulative total for each rank placed at the c_k value for the last year the rank is normally held. Accordingly, c_5 was set at 1 because of the unlikely event of attrition by lieutenants selected for SEP, c_{10} was set at 0.6, c_{16} at 0.65, c_{22} at 0.4, and all other c_k at 1. A yearly continuation fraction from Appendix B was not used for each c_k because it was found to bias the quota projections. This is illustrated in Figure 5 for SEP MOS 9650. The bias occurs because in both transient models' formulations, for any $c_k < 1$, both students and officers in an initial SEP tour are subjected to attrition. This attrition is unlikely to occur for the Marine Corps according to assumption 7.

When perusing the quota projections, it should be noted that the sum of the quotas by rank may differ from the quota total by one officer. This is due to rounding.

Complete quota projections for a twenty year period under base case conditions are given for SEP MOS 9650 in figure 3. The quota projections demonstrate the need to look at quota determinations from a long range perspective. The first and second years' quotas are 7 and 9 officers respectively. The third year's quota is 15 officers. It may be more practical to send part of the third year's quota to school in years one and two. The projections show quotas occurring in three year cycles beginning in year seven. These cycles often occur when using the basic transient model. The smoothed transient model is of particular usefulness in this case in order to reduce the variance of the quota size from year to year. The results of applying the smoothed transient model under base case conditions for SEP MOS 9650 are shown in figure 6.

C. SENSITIVITY ANALYSIS

The lower bound totals for the basic transient model are contained in Figure 7 for SEP MOS 9650. The lower bound was found by setting $c_k = 1$ for all k.

Both models were sensitive to the selection of l_i. If the delay period (d) occurs during the years of service in which a cumulative continuation fraction is applied, then a significant proportion of the students will be attrited before reaching the first year of their initial SEP tour

(l_i). Thus, the basic transient and smoothed transient models adjust $Q_i(t)$ upward to compensate for the student loss. This situation was avoided by ensuring that l_i was set at a year which is greater than, or equal to, at least d years after the year the previous continuation fraction was applied. For example, if d = 2 and a cumulative continuation fraction was applied in year 10, then l_i (for i = 4) should be set no earlier than year 13.

The years of service (k) for officers and students was determined by calculating the difference between 1977 and the date the officer accepted his or her first commission. Since some officers have prior enlisted service, the years of service were also calculated based on an officer's armed forces active duty base date (AF ACDU BD). Service dates (SD) too were used to calculate years of service since these dates might give a better indication of when an officer is eligible for promotion. For SEP MOS 9650, the SEP trained officer inventory was found to be "older" when using AF ACDU BD or SD. Therefore, quota projections were slightly larger in the first five years of projections. The increase, however, averaged only one more officer a year.

Sensitivity analysis was conducted on the cumulative continuation fractions (c_5=1, c_{10}=0.6, c_{16}=0.65, and c_{22}=0.4) under base case conditions for both over and under estimations of the true c_k by 0.05 and 0.1. The results for SEP MOS 9650 are contained in Figure 7.

Year (t)	CAPT $Q_3(t)$	MAJ $Q_4(t)$	LTCOL $Q_5(t)$	COL $Q_6(t)$	TOTAL
1		6			7
2	5	4			9
3	2	13			15
4	3	6			9
5	8				8
6	2	14			16
7	3	5			8
8	8	1			9
9	2	14			16
10	3	5			8
11	8	1			9
12	2	14			16
13	3	5			8
14	8	1			9
15	2	14			16
16	3	5			8
17	8	1			9
18	2	14			16
19	3	5			8
20	8	1			9

Figure 3. MOS 9650 Quotas (Base Case) using Basic Transient Model.

Yrs of Svc	Current Inventory FY77	Student Additions to Inventory FY78	FY79	Continuation Rates	SEP Billets	
1				1		
2				1		
3				1		
4		1		1		
5		1	2	1		
6		1	2	1		
7	1	1	1	1		
8	2			1	13	CAPT Billets
9	2			1		
10	1	1	1	0.6		
11	5			1		
12	6			1		
13	7			1		
14	15			1	28	MAJ Billets
15	14			1		
16	4		1	0.65		
17	8			1		
18	6			1		
19	11			1		
20	5			1	17	LTCOL Billets
21	1			1		
22	4			0.4		
23	2			1		
24	4			1		
25				1		
26	2			1	1	COL Billets
27				1		
28				1		
29				1		
30				0		

Figure 4. MOS 9650 Data for Basic Transient Model.

Year (t)	CAPT $Q_3(t)$	MAJ $Q_4(t)$	LTCOL $Q_5(t)$	COL $Q_6(t)$	TOTAL
1		8	8		16
2	8	7			15
3	4	15			20
4	4	9			13
5	10	3	5		18
6	5	15			20
7	4	8	1		14
8	9	4	4		18
9	5	14			19
10	5	9	2		15
11	9	5	4		18
12	5	13			19
13	5	9	2		16
14	8	6	3		17
15	6	12			18
16	5	9	2		16
17	8	6	3		17
18	6	12			18
19	5	9	2		16
20	8	7	3		17

Figure 5. Transient Model Quota for MOS 9650 Using Yearly Continuation Rates.

Year (t)	CAPT $Q_3(t)$	MAJ $Q_4(t)$	LTCOL $Q_5(t)$	COL $Q_6(t)$	TOTAL
1	1	9	3		13
2	1	8			9
3	4	8			12
4	4	9	1		14
5	4	3			8
6	4	7			11
7	4	7			11
8	4	7			11
9	4	7			11
10	4	7			11
11	4	7			11
12	4	7			11
13	4	7			11
14	4	7			11
15	4	7			11
16	4	7			11
17	4	7			11
18	4	7			11
19	4	7			11
20	4	7			11

Figure 6. Smoothed Transient Quotas (Base Case) for MOS 9650.

Year	Lower Bound	Changes in c_k				
		+0.10	+0.05	0.00	-0.05	-0.10
1	6	6	7	7	7	7
2	8	9	9	9	10	11
3	14	15	15	15	15	16
4	9	9	9	9	10	10
5	8	8	8	8	9	11
6	11	15	15	16	16	17
7	7	8	8	8	8	9
8	10	9	9	9	10	12
9	11	15	15	16	16	17
10	7	8	8	8	8	9
11	10	9	9	9	10	12
12	11	15	15	16	16	17
13	7	8	8	8	8	9
14	10	9	9	9	10	12
15	11	15	15	16	16	17
16	7	8	8	8	8	9
17	10	9	9	9	10	12
18	11	15	15	16	16	17
19	7	8	8	8	8	9
20	10	9	9	9	10	12
Total	185	207	208	213	221	245
Average Quota	9.3	10.4	10.4	10.7	11	13.3

Figure 7. Sensitivity Analysis on Transient Model Parameter, c_k, for MOS 9650.

VI. CAREER PATH TRANSIENT MODEL

A. MODEL DESIGN

1. General Description

Given the present inventory of SEP graduates and students in a particular MOS, this model determines future student quotas for a planning period of any number of years.

The basic method used in this model is to create a limited number of career paths which generally depict the flow of officers through the SEP program--from graduate school through utilization in successive SEP tours. With the present inventory of SEP officers and students placed on the career paths, the model estimates the number of officers that will be available to fill SEP billets during any future year t. This number is subtracted from the number of SEP billets in the MOS, and the result is the number of officers (i.e. the quota) which the Marine Corps will have to graduate from SEP in year t in order to fill billet vacancies which are predicted to occur in that year.

2. Assumptions

1. An officer will hold the following ranks during the given years of commissioned service:

Rank	Yrs of Svc
1STLT	2 - 5
CAPT	6 - 10
MAJ	11 - 16
LTCOL	17 - 22
COL	23 - 30

2. If "d" represents the delay between selection for SEP and entering an initial SEP tour, then the Marine Corps must select a first lieutenant for SEP in year t in order to fill a vacant captain's billet in year (t+d). Likewise, a "senior" captain or a "junior" major must be selected in year t in order to fill a vacant major's billet in year (t+d), and a "junior" lieutenant colonel must be selected in year t in order to fill a vacant lieutenant colonel's billet in year (t+d).

3. SEP graduates will be assigned to a SEP billet immediately upon completion of school. The only exception to this policy will be the officer who is due for a one-year, unaccompanied, overseas tour. In such cases, the officer will be placed in a SEP billet immediately upon completing the overseas tour.

4. The average length of graduate school in the SEP program is 2 years.

5. The standard tour length is three years.

6. No attrition will occur among SEP officers during graduate school or during their initial SEP tour.

7. Adequate student input is available to meet

quotas.

3. Career Paths

This model is based on five career paths which generally depict the flow of officers through SEP (Figure 8). The paths are constructed on the basis of the assumptions listed above. For example, in path 1, an officer starting school with approximately 5 years of commissioned service will eventually serve in an initial SEP tour as a captain. In paths 2 and 3 officers who start school with approximately 9 and 12 years of service respectively will serve in initial SEP tours as majors. In path 4 an officer who starts school with approximately 17 years of service will eventually serve an initial SEP tour as a lieutenant colonel. Path 5 is optional. Reference 1 does not provide for sending a colonel to SEP. Instead, it depends on filling billet vacancies in this rank with previously SEP-trained officers who reach the rank of colonel. If there is an insufficient number of SEP-trained colonels to meet billet requirements, the Marine Corps has three options:

1. Fill colonel billet vacancies with non-SEP colonels.

2. Fill the vacancies with SEP-trained lieutenant colonels.

3. Leave the billets vacant.

If the Marine Corps chooses option 2 then path 5 may be incorporated in the model and will provide for sending a lieutenant colonel to school to eventually fill a colonel's billet.

Reutilization of SEP graduates in SEP tours is also incorporated into the model. Figure 8 illustrates an every-other-tour policy for SEP utilization, allowing 4 years of non-SEP duty between SEP tours. During the non-SEP assignments it is assumed that the officer would be available for a three year assignment to a regular tour of duty in his primary MOS and a one year assignment to a service school or unaccompanied overseas tour, etc. Figure 9 illustrates the 5 career paths under an every-third-tour policy which allows 7 years of non-SEP duty between SEP tours.

4. Predicting Billet Vacancies

The set of career paths provides a means to categorize the present inventory. After each graduate and student in the inventory has been placed on one of the paths, the inventory is "aged" or projected into the future in order to determine for a future year t:

a. The portion of the inventory that will remain in year t.

b. The number of officers in the remaining inventory who will be serving in SEP billets in year t.

After item b above has been determined, this number is subtracted from the total number of billets in the SEP MOS. The result is the number of vacancies which will have to be filled by educating additional officers.

Specifically, billet vacancies may be determined in the following manner. Consider the SEP MOS fixed and let:

Subscript i on the variables indicate rank as follows--

Subscript	Rank
3	Capt
4	Maj
5	LtCol
6	Col

$I_{pk}(t)$ = Inventory in career path p in year t with k years of service, k=1,2,...,30, t=0,1,2,..., p=1,2,3,4,5.

Period t=0 is the current period.

Example: Figure 8 gives the inventory for Fiscal Year 1977. If t=0 represents Fiscal Year 1977 and p=2 and k=14, then $I_{2,14}(0) = 11$.

C_{pk} = Fraction of those officers in path p with k years of service who will remain to have (k+1) years of service, p=1,2,3,4,5, k=1,2,...30.

Example: In Figure 8, when p=2 and k=17, $C_{2,17} = .8$

l_{ip} = Year of service when a rank i SEP billet is entered on path p, i=3,4,5,6, p=1,2,3,4,5.

u_{ip} = Last year of service for a rank i SEP billet on path p, i=3,4,5,6, p=1,2,3,4,5.

Example: When i=5 and p=4, $l_{5,4} = 19$ and $u_{5,4} = 21$.

B_i = Number of SEP billets in rank i.

$V_i(t)$ = Vacancies which occur in SEP billets in rank i during year t.

d = "delay" between selection for SEP and entering a SEP billet.

$q_i(t)$ = School quota in year t for input into rank i SEP billets in year (t+d).

As shown in Figure 8, each path is assigned its own set of continuation rates. In accordance with assumption 6, all C_{pk} are set at 1 for the years an officer is in school and during his initial payback tour. Commencing with the final year of the initial tour, the inventory in each path is subjected to normal attrition.

Future inventories are given by:

$$I_{p(k+1)}(t+1) = C_{pk} I_{pk}(t) \qquad \text{(VI.1)}$$

where k=0,1,...,29, p=1,2,3,4,5, and $I_{p,0}(t) = 0$. This is illustrated using Figure 8. Let Figure 8 represent the inventory at t=0. When p=2 and k=17 using (VI.1):

$$I_{2,18}(1) = C_{2,17} I_{2,17}(0) = .8(6) = 4.8$$

It is useful to regard future inventories as "legacies" of

past inventories. Thus $I'_{p(k+1)}(t+1)$ is the legacy of $I_{pk}(t)$. Therefore:

$$I'_{p(k+1)}(t+1) = C_{pk} I_{pk}(t) \qquad \text{(VI.2)}$$

To determine the future number of vacant SEP billets in each rank for year t, the legacies in year t of the present inventory must first be calculated as discussed above. Next, the number of officers serving in rank i SEP billets during year t must be determined. For a future year t>0 the total inventory serving in rank i SEP billets is given by:

$$\sum_{p=1}^{5} \sum_{k=1_{ip}}^{u_{ip}} I'_{pk}(t) \qquad i=3,4,5,6 \qquad \text{(VI.3)}$$

For example, if Figure 8 gives the inventory in year t, then using equation (VI.3), the total inventory serving in SEP billets in rank i=4 is:

$$\sum_{p=1}^{5} \sum_{k=1_{4p}}^{u_{4p}} I'_{pk}(t) = 4+2+1+4+5+5+0+0+2 = 23.$$

Finally vacancies in each rank are calculated for year t by:

$$V_i(t) = \text{Max}\,[0,\ B_i - \sum_{p=1}^{5} \sum_{k=1_{ip}}^{u_{ip}} I'_{pk}(t)]. \qquad \text{(VI.4)}$$

Using Figure 8 as an example of the inventory in year t, the billet vacancies for rank i=4 in year t according to (VI.4) would be:

$$V_4(t) = \text{Max}[0,\ 28 - 23] = 5.$$

5. Quota Determination

SEP quotas for any year t are given by

$$q_i(t) = V_i(t+d). \qquad \text{(VI.5)}$$

Quotas in year t are set exactly equal to the vacancies in year (t+d) because of assumption 6.

For example, assume an officer is selected for SEP in 1978, starts school the next year, and has a two year curriculum with no overseas tour after graduation. The value of "d" would be determined as follows:

t	Year	
0	'78	Selection for SEP
1	'79	1st year in school
2	'80	2nd year in school
3	'81	Initial SEP tour

Years 1978 through 1980 inclusive constitute a three year delay. Therefore, to determine 1978 SEP quotas:

$$q_i(0) = V_i(0+3)$$

In this example 1978 quotas will be equal to 1981 billet vacancies.

The quotas given by (VI.5) become a part of the inventory, $I_{pk}(t+1)$, and are shown in the first year of graduate school. Since there are two career paths which assign new graduates to major's billets, q_4 must be split between them. Using a value "a" ($0 \leq a \leq 1$), q_4 is multiplied by the factors (a) and (1-a) and assigned to paths 2 and 3 respectively. Therefore in $I_{pk}(t+1)$:

$$q_3(t) = I_{1,5}(t+1) \tag{VI.6}$$

$$[q_4(t)](a) = I_{2,9}(t+1) \tag{VI.7}$$

$$[q_4(t)](1-a) = I_{3,12}(t+1) \tag{VI.8}$$

$$q_5(t) = I_{4,17}(t+1) \tag{VI.9}$$

$$q_6(t) = I_{5,21}(t+1) \tag{VI.10}$$

The values of $I_{pk}(t+1)$ are now used in (VI.1) through (VI.5) to calculate $q_i(t+1)$. This procedure continues until all quotas are determined.

B. MODEL APPLICATION

Quotas for a planning period of any length may be quickly calculated by use of the APL functions, QUOTA1 and QUOTA2, provided in Appendix C. QUOTA1 models the every-other-tour utilization policy and QUOTA2 models the

every-third-tour policy. Both functions calculate quotas using equations (VI.1) through (VI.10). Using the billet requirements shown in Appendix A for B_i, setting A=.5, and using the CR values of Appendix B, quota projections using QUOTA1 and QUOTA2 are presented for MOS 9650 in Figures 10 and 11 respectively.

The global variables--BI, CR and A--of each function, as discussed in Appendix C, allow the user to vary the parameters of the two models. For instance, one might wish to change the values of BI to see how an increase or decrease in the number of billets in a given MOS would affect student quotas. By varying A the user could determine how changing the split of the major's quota between paths 2 and 3 would affect quotas. Also different continuation rates may be used by changing the value of CR.

C. SENSITIVITY ANALYSIS

Sensitivity analysis is demonstrated using the quotas in Figure 10 as the base case. QUOTA1 shown in Figure 10 as the base case. Three aspects of the model were subjected to sensitivity analysis: Placement of the inventory on the career paths, CR values, and the variable A.

1. Three different methods of placing the inventory on the career paths were tried and their output compared in Figure 12:

<u>METHOD 1</u>. Using personnel data obtained from Headquarters Marine Corps, each member of the inventory was considered individually as to years of commissioned service, current assignment and date of last SEP assignment. The aim

of this methcd was to achieve the most accurate "fit" of the inventory on the career paths. The average annual quota was 15 and the total twenty year quota was 299.

METHOD 2.The aim of this method is to reduce the work involved in inventory placement by merely assigning all graduates to path 1 while taking care in placing students in order to accurately reflect their enterance into an initial SEP tour. Using this method all SEP graduates were placed into path 1 according to years of commissioned service. Students were placed in the school period (i.e. the years immediately preceding the initial SEP tour) according to when they would actually enter into the initial SEP tour. For example, consider a major with 11 years of service who is in his last year of graduate school and who is due for an overseas tour. This method would ignore his years of service and place him in year 12 of path 3. Thus, during the year he is overseas, the model would regard him as being in his final year of school. When the major finally returns from overseas and is assigned to a SEP billet, the model would show him in the first year of an initial SEP tour. Using this method, the average annual quota was 14.5 and the total twenty year quota was 293.

METHOD 3. All SEP graduates were placed in path 1 according to years of commissioned service, and students were placed into the school period of the paths according to years of service. The average annual quota was 15 and total twenty year quota was 299. (This method of inventory placement is used in the base case.)

2. Model sensitivity to changes in the variable CR was tested by varying it and keeping all other parameters constant at the base case values. The CR values were varied by ±.01, ±.02 and ±.05. A lower bound quota was also calculated by setting all CR values at 1. Results of this

analysis are shown in Figure 13.

3. The function parameter A was also varied to determine how variations in the split of the major's quota between paths 2 and 3 would affect quotas over the entire planning period. "A" represents the portion of the major's quota assigned to path 2, and (1-A) represents the portion of the major's quota assigned to path 3. Holding all other parameters constant at base case values, A was varied as follows:

A	20 Year Quota	Average Quota
1	287	14.4
.8	291	14.6
.6	296	14.8
.5	299	14.9
.4	300	15
.2	305	15.3
0	312	15.6

Yrs of Svc k	p = 1 c_{1k}		I_{1k}	p = 2 c_{2k}		I_{2k}	p = 3 c_{3k}		I_{3k}	p = 4 c_{4k}		I_{4k}	p = 5 c_{5k}		I_{5k}	SEP Billets
1																
2																
3																
4																
5	1	NPS	4													
6	1		3													
7	1															
8	1	SEP	2													$B_3 = 13$
9	.85			1		2										
10	.85		1	1	NPS	4										
11	.94		2	1		4										
12	.94		1	1	SEP	5	1	NPS	1							
13	95		2	*		5	1									$B_4 = 28$
14	.95		4	*		11	1									
15	.95	SEP	2	*		12	1	SEP								
16	.95		1	*		1	*		2							
17	.80		1	*		6	*		1	1	NPS					
18	77		2	*		3	*		1	1						
19	.73			*	SEP	4	*		5	1		2				
20	.95			*		3	*		3	1	SEP					$B_5 = 17$
21	.94			*			*			*			1	NPS		
22	.94	SEP	1	*		2	*	SEP	1	*			1			
23	.64			*		1	*		1	*			1			
24	.80		1	*		1	*			*		2	1	SEP		
25	.73			*			*			*			*			
26	85		1	*	SEP		*		1	*			*			
27	.88			*			*			*	SEP		*			$B_6 = 1$
28	.09			*			*			*			*			
29	1	SEP		*			*	SEP		*			*			
30	0			*			*			*			*			

* $c_{ik} = c_{1k}$

Figure 8. MOS 9650 FY77 Data for Career Path Transient Model.

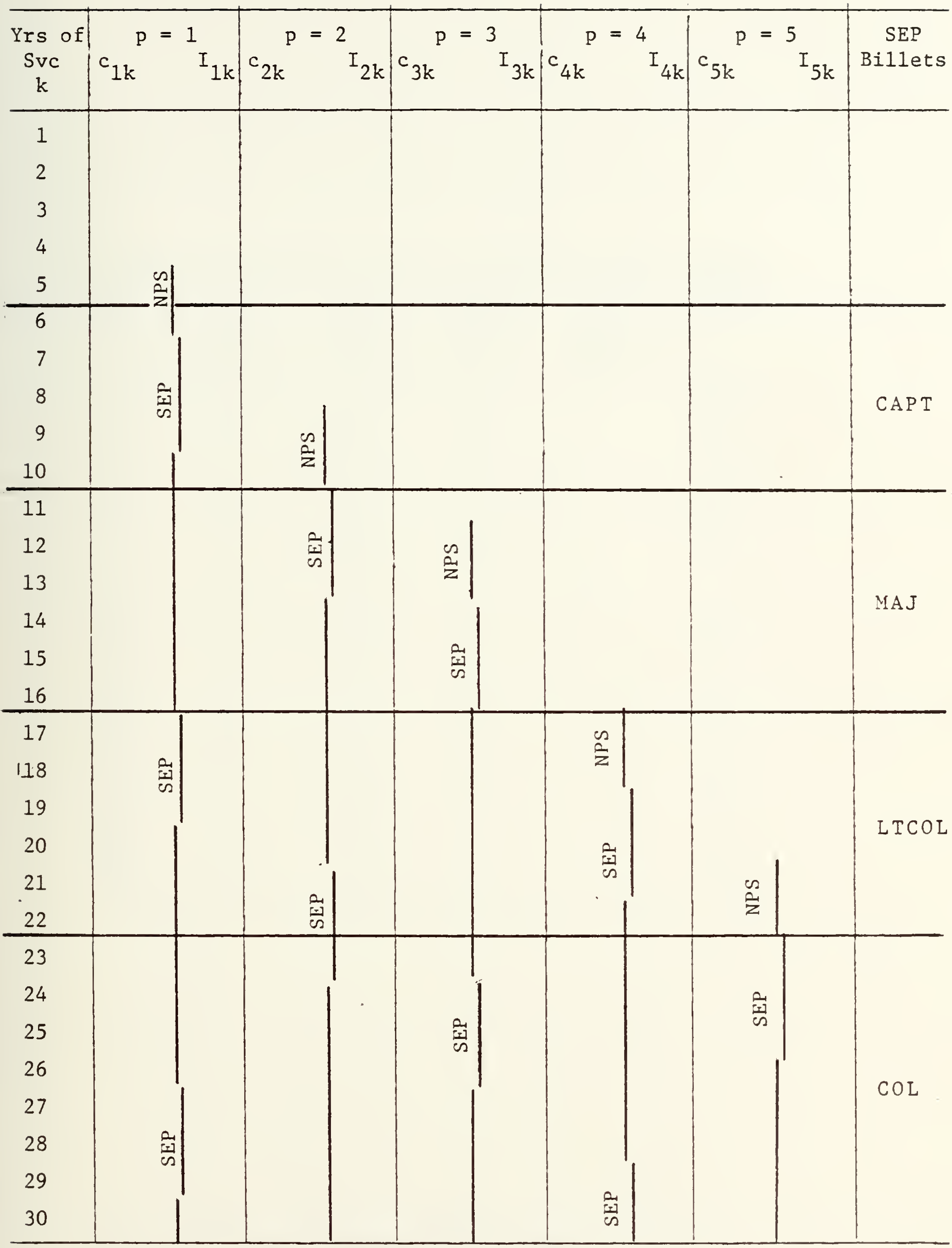

Figure 9. Career Path Design for an Every-Other-Tour Utilization Policy.

Year (t)	CAPT $Q_3(t)$	MAJ $Q_4(t)$	LTCOL $Q_5(t)$	COL $Q_6(t)$	TOTAL
1	6	11	6		23
2	3	8	4		15
3	3	4	2		9
4	7	13	5		25
5	3	7			10
6	3	4	4		11
7	7	12	8		27
8	3	5			8
9	3	4			7
10	7	12	9		28
11	3	5			8
12	3	4			7
13	7	12	8		27
14	3	5			8
15	3	4			7
16	7	12	9		28
17	3	5			8
18	3	4			7
19	7	12	9		28
20	3	5			8

Figure 10. MOS 9650 Quotas Using *Quotal*.

Year (t)	CAPT $Q_3(t)$	MAJ $Q_4(t)$	LTCOL $Q_5(t)$	COL $Q_6(t)$	TOTAL
1	6	26			32
2	3	2			5
3	3				3
4	1	26	7		34
5	6	2	4		12
6	3		3		6
7	3	26	8		37
8	1	2	3		6
9	6		2		8
10	3	26	8		37
11	3	2			5
12	1				1
13	6	26	13		45
14	3	2			5
15	3				3
16	1	26	13		40
17	6	2			8
18	3				3
19	3	26	14		43
20	1	2			3

Figure 11. MOS 9650 Quotas Using *Quota2*.

Year	Method 1	Method 2	Method 3
1	24	18	23
2	8	17	15
3	9	14	9
4	29	20	25
5	10	13	10
6	9	13	11
7	29	21	27
8	5	10	8
9	7	11	7
10	32	21	28
11	5	10	8
12	7	11	7
13	32	20	27
14	5	10	8
15	7	11	7
16	32	20	28
17	5	11	8
18	7	11	7
19	32	19	28
20	5	12	8
Total	299	293	299
Average Quota	15	14.5	15

Figure 12. MOS 9650 Career Path Transient Quotas Using Three Methods of Inventory Placement.

Year	Lower Bound	Changes in c_{ip} +0.05	+0.02	+0.01	0.00	-0.01	-0.02	-0.05
1	14	19	21	23	23	24	25	28
2	13	15	15	15	15	14	15	14
3	9	9	9	8	9	9	7	7
4	18	21	24	25	25	27	29	31
5	9	10	10	10	10	10	11	12
6	6	8	9	10	11	9	7	7
7	19	25	28	28	27	31	32	33
8	5	7	7	7	8	6	8	8
9	6	6	6	7	7	6	5	5
10	17	24	28	28	28	33	33	35
11	5	7	7	6	8	5	8	8
12	6	6	6	7	7	6	5	5
13	17	23	27	29	27	34	32	35
14	5	7	7	5	8	4	8	8
15	6	6	6	7	7	6	5	5
16	17	23	28	31	28	35	33	35
17	5	7	7	4	8	3	8	8
18	6	6	6	7	7	6	5	5
19	17	23	28	32	28	37	33	35
20	5	7	7	3	8	3	8	8
Total	205	259	286	292	299	308	317	332
Average Quota	10.5	13	14.3	14.6	15	15.4	15.9	16.6

Figure 13. Sensitivity Analysis on Career Path Transient Model Parameter, c_{ip}, for MOS 9650.

VII. CAREER PATH STEADY STATE MODEL

A. MODEL DESIGN

1. General Description

The set of career paths described in Chapter VI also forms the basis for this steady state model. The annual SEP quotas which correspond to each of the paths are regarded in this model as manpower resources which the Marine Corps wishes to conserve. Using linear programmining (LP), this model minimizes the total annual quota subject to the constraint of meeting the average annual billet requirements of a given MOS.

2. LP Problem Formulation

Consider the SEP MOS fixed and let:

Subscript i on the variables indicate rank as follows--

Subscript	Rank
3	Capt
4	Maj
5	LtCol
6	Col

x_p = Annual quota corresponding to path p. p=1,2,3,4,5

c_p = The cost associated with x_p. p=1,2,3,4,5

a_{ip} = The fraction of the path p quota which remains in the Marine Corps to serve in a SEP billet in rank i, i=3,4,5,6, p=1,2,3,4,5.

B_i = Billets in rank i, i=3,4,5,6.

T_i = Tour length for rank i, i=3,4,5,6.

In general terms the LP problem is expressed as follows:

Minimize:

$$c_1x_1 + c_2x_2 + c_3x_3 + c_4x_4 + c_5x_5 = \Phi \quad \text{(VII.1)}$$

Subject to:

$$a_{i1}x_1 + a_{i2}x_2 + a_{i3}x_3 + a_{i4}x_4 + a_{i5}x_5 \geq B_i/T_i \quad \text{(VII.2)}$$

$$x_p \geq 0$$

i=3,4,5,6.

The objective function (VII.1) represents the quota which is to be minimized. It is useful to regard quotas as manpower resources which the Marine Corps wishes to conserve. (i.e. the Marine Corps desires to determine the minimum quota necessary to meet SEP billet requirements.). B_i/T_i

represents the average number of billets which become vacant each year (assuming steady state flows). In terms of the LP problem, each B_i/T_i may be regarded as a requirement which consumes resources. The left-hand side of each constraint (VII.2) may be regarded as the sum of the various resources which can be used to meet the billet requirements for each rank. The value of each a_{ip} represents the fraction of each resource which will be available to meet each B_i/T_i.

a. Formulation for an Every-Other-Tour Policy

The coefficients in the constraints of the LP problem depend on the design of the career paths. As illustrated in Figure 8, under an every-other-tour policy an officer serves in a SEP tour once during each rank. The following table shows with x's which paths provide officers for SEP billets in each rank:

Paths 1	2	3	4	5	Billets
x					CAPT
x	x	x			MAJ
x	x	x	x		LTCOL
x	x	x	x	x	COL

On the basis of these observations the LP problem is formulated as follows using data from Figure 8:

$$\text{Minimize:} \quad x_1 + x_2 + x_3 + x_4 + x_5 = \Phi$$

Subject to:

$$
\begin{aligned}
x_1 & & & & & \geq 13/3 \\
.7x_1 + x_2 + x_3 & & & & & \geq 28/3 \\
.5x_1 + .8x_2 + .95x_3 + x_4 & & & & & \geq 17/3 \\
.2x_1 + .3x_2 + .40x_3 + .9x_4 + x_5 & & & & & \geq 1/3 \\
& & & & x_p & \geq 0.
\end{aligned}
$$

In the objective function, $c_p = 1$ for $p=1,2,3,4,5$ because the costs associated with all of the quotas were assumed to be equal in this example. The a_{ip} values were determined by finding the cumulative product of all the C values in Figure 8 for path p prior to rank i. For example:

$$a_{4,1} = 1 \bullet 1 \bullet 1 \bullet 1 \ (.85)\ (.85) = .7$$

In words, this means that, on a year to year basis, 70 percent of the path 1 quota will remain in the Marine Corps to eventually serve in SEP billets in the rank of major.

b. Formulation for an Every-Third-Tour Policy

To further illustrate problem modelling, the LP problem is presented under an every-third-tour policy. From Figure 9, it can be determined which paths will provide officers for SEP billets in each rank; they are as follows

Paths					
1	2	3	4	5	Billets
x					CAPT
	x	x			MAJ
x	x		x		LTCOL
x		x	x	x	COL

On the basis of this observation of the every-third-tour policy, the LP problem is formulated as follows:

Minimize: $x_1 + x_2 + x_3 + x_4 + x_5 = \Phi$

Subject to:

$$x_1 \geq 13/3$$

$$x_2 + x_3 \geq 28/3$$

$$.5x_1 + .8x_2 + x_4 \geq 17/3$$

$$.2x_1 \quad .4x_3 + .9x_4 + x_5 \geq 1/3$$

$$x_p \geq 0.$$

B. MODEL APPLICATION

Since the LP problem used in this model is small (5 variables and 4 constraints), it can be solved by hand, using the simplex method, or it can more easily be solved by use of the linear programming routines available in most time-sharing computer libraries.

The solution of the LP problem gives a miminum steady state quota. For the every-other-tour problem formulated above the optimal solution was $x_1=4$ and $x_3=7$ as shown in Figure 14. According to assumption 2 in Chapter VI, this solution can be interpreted as an annual quota of 4 first lieutenants and 7 majors for the 9650 MOS. (The solution may present career path quotas and the total quota in fractional form. The decision as to how to round these solutions to integer values is a matter of preference. It is recommended that the total quota be rounded up for any fraction to assure that steady state flow rates are met. This rounded total can then be apportioned among the career paths according to their relative values in the solution.) For the every-third-tour LP problem formulated above, the optimal solution as shown in Figure 15 is $x_1=4$, $x_2=5$ and $x_3=5$ which can be interpreted as 4 first lieutenants, 5 captains and 5 majors.

C. SENSITIVITY ANALYSIS

Sensitivity analysis can be conducted on the LP problem

used in this model by varying the parameters: a_{ip}, C_p, B_i and T_i. To illustrate, let the LP problem formulated above for the every-other-tour policy serve as the base case.

Item 1 of Figure 16 gives the base case quota. Items 2 through 5 show the change in quotas as the a_{ip} base case values are varied ±.05 and ±.10. As the a_{ip} values vary over the range ±.10 from the base case, the total quota rises from 11 to 12. Item 6 illustrates how quotas vary with respect to changes in the ratio B_i/T_i. In item 6 when tour length changes to $T_i=4$, the total quota drops from 11 to 8. Item 7 demonstrates how quotas change when C_p is varied. C_p is the cost (or price) to the Marine Corps of each officer it sends to SEP. If the quota corresponding to a certain career path were considered to be more costly than the others, C_p could be given a higher value for that career path to signify the higher cost. In item 7, when C_3 was given the value 2, the major's quota switched from career path 3 to path 2 in the new solution.

The shadow prices, constraint ranges and price ranges which may be gleaned from the optimal solution of any LP problem also provide useful information in this model. Figure 14.a provides a printout of the solution of the base case LP problem.

The zero value for variable 2 in the shadow prices indicates that there is an alternate optimal solution to the base case problem which would not change the total quota of

the objective function. A zero shadow price for x_2 means that x_2 could become one of the solution variables, forcing x_1 or x_3 to leave, but the total quota would remain the same. The small size of this problem allows one to see immediately that if x_2 became a solution variable that x_3 would have to leave in order to keep the value of the objective function unchanged. In terms of the base case problem, the zero shadow price reveals that in addition to the quota $x_1=4$ and $x_3=7$, the quota $x_1=4$ and $x_2=7$ is also an optimal sclution.

The constraint ranges shown in Figure 14.a show the range of values over which B_i/T_i may vary without changing the variables in the solution. It is important to note that when B_i/T_i varies within these ranges, the value of the solution variables may change--thus changing the value of the objective function--but the set of variables (i.e. the career paths) involved in the solution will not change. Therefore, the constraint ranges of Figure 14.a reveal that when the constraints rise above or fall below their respective upper and lower limits, a new set of solution variables will emerge. Likewise, when the C_p values in the objective function rise above or fall below the price ranges shown in Figure 14.a, the set of solution variables will change.

$$Z = X1 + X2 + X3 + X4 + X5$$

SUBJECT TO

$$
\begin{aligned}
X1 & & & & & \geq 4.33 \\
.7X1 + X2 + X3 & & & & & \geq 9.33 \\
.5X1 + .8X2 + .95X3 + X4 & & & & & \geq 5.67 \\
.2X1 + .3X2 + .40X3 + .9X4 + X5 & & & & & \geq .33
\end{aligned}
$$

OPTIMAL VALUE OF OBJECTIVE FUNCTION IS 10.629

VARIABLE 01 AT LEVEL 4.33
VARIABLE 03 AT LEVEL 6.299
VARIABLE 08 AT LEVEL 2.47905
VARIABLE 09 AT LEVEL 3.0556

Figure 14. Formulation and Optimal Solution of the Career Path Steady State Model for MOS 9650.

VARIABLE 2 SHADOW PRICE	0
VARIABLE 4 SHADOW PRICE	1
VARIABLE 5 SHADOW PRICE	1
VARIABLE 6 SHADOW PRICE	0.3
VARIABLE 7 SHADOW PRICE	1

CONSTRAINT 1	0	4.33	13.33
CONSTRAINT 2	6.72	9.33	$+\infty$
CONSTRAINT 3	$-\infty$	5.67	8.15
CONSTRAINT 4	$-\infty$	0.33	3.39

PRICE 1	0.7	1	$+\infty$
PRICE 2	1	1	$+\infty$
PRICE 3	0	1	1
PRICE 4	0	1	$+\infty$
PRICE 5	0	1	$+\infty$

Figure 14.a. Shadow Prices, Constraint Ranges and Price Ranges of Optimal Solution for the Career Path Steady State Model for MOS 9650.

$$Z = X1 + X2 + X3 + X4 + X5$$

SUBJECT TO

$$\begin{array}{llllll}
X1 & & & & & \geq 4.33 \\
 & X2 + & X3 & & & \geq 9.33 \\
.5X1 + & .8X2 + & & X4 & & \geq 5.67 \\
.2X1 + & & .4X3 + & .9X4 + & X5 & \geq .33
\end{array}$$

OPTIMAL VALUE OF OBJECTIVE FUNCTION IS 13.66

VARIABLE 01 AT LEVEL 4.33
VARIABLE 02 AT LEVEL 4.38125
VARIABLE 03 AT LEVEL 4.94875
VARIABLE 09 AT LEVEL 2.5155

Figure 15. Formulation and Optimal Solution of the Career Path Steady State Model for MOS 9650 Based on an Every-Third-Tour Utilization Policy.

	Optimal Solution x_1	x_2	x_3	x_4	x_5	Total
1. Base Case	4		7			11
2. Base Case a_{ip} + 0.10	4		7			11
3. Base Case a_{ip} + 0.05	4		7			11
4. Base Case a_{ip} - 0.05	5		7			12
5. Base Case a_{ip} - 0.10	5		7			12
6. $T_i = 4$	3		5			8
7. $C_3 = 2$	4	7				11

Figure 16. Sensitivity Analysis on Parameters, a_{ip}, T_i and C_3, of the Career Path Steady State Model for MOS 9650.

VIII. MODEL ADVANTAGES AND LIMITATIONS

A. STEADY STATE MODELS

1. Advantages

a. General Advantages of the Steady State Approach

The steady state and steady state career path models provide a simplified means of making quota determinations by reducing the problem to a single decision process. The quota results are the average student inputs per year necessary to meet the average number of billet vacancies per year. The quotas remain fixed for all periods unless the assumptions, parameters, or values of the variables are changed.

b. The Basic Steady State Model

The steady state model facilitates understanding of the impact on SEP requirements, in terms of graduate education quotas, for changes to the billet structure, tour lengths, and officer utilization and retention rates.

c. The Career Path Steady State Model

The multiple career path design of this model allows the user to modify the number of career paths and the location of the SEP tours within them. The every-third-tour LP problem as compared to the every-other-tour LP problem is an example of this flexibility. In addition, use of linear programming in this model assures the planner of a minimized quota.

2. Limitations

a. General Limitations of the Steady State Approach

Both steady state models determine quotas necesssary to meet average annual billet vacancies. But, neither model accounts for for the real personnel inventory currently existing for a SEP discipline. The models operate as though manpower availability and eligibility, and student inputs, have historically equalled the modelled and projected personnel flows being used to forecast future quotas. the models do not provide quotas which compensate for present shortages or surpluses of SEP personnel.

b. The Basic Steady State Model

The steady state model does not readily adapt to modelling SEP tour policies other than the "every other tour" policy.

c. The Career Path Steady State Model

The application of continuation rates in this model is subjective and relies a great deal on the judgement of the user.

B. TRANSIENT MODELS

1. advantages

a. General Advantages of the Transient Approach

This type of model enables the planner to take into account the trained personnel already available in the current inventory and to model the use of these personnel assets across time when calculating future quotas.

b. The Basic Transient Model

The basic transient model, when used for making long range quota projections, will show cyclical quota trends that may be experienced due to an unbalanced inventory. By identifying when the high and low quota periods can be expected to occur, adjustments can be made to these and other periods' quotas to offset the cycles. Or, at least, a planner will be aware that the quotas may vary significantly from year to year.

c. The Smoothed Transient Model

The smoothed transient model effectively reduces the variance of an otherwise cyclical quota. Over time the smoothed transient model's quota will approach or equal the steady state quota, and should remain constant thereafter.

d. The Career Path Transient Model

The multiple career path design allows the user to model any type of utilization policy for SEP assets by modifying the basic design. For example, more or fewer career paths may be used. The years designated as SEP tours may also be varied. Only slight modifications to the basic APL functions provided in Appendix C are necessary to reflect different utilization policies. The every-third-tour model as compared to the every-other-tour model is an example of how the model design may be varied.

The multiple career path design also allows a unique set of continuation rates to be applied to each path. This results in a more realistic modelling of inventory attrition. Continuation rates for the years an officer is in school and serving in an initial SEP tour may be set at 1 to reflect the fact that virtually all of the officers selected for SEP complete graduate school and then are required to remain in the Marine Corps long enough to serve in an initial SEP tour. At the termination of the initial SEP tour, the continuation rates for each path are able to reflect normal attrition of officers from the inventory during the ensuing years.

2. Limitations

a. General Limitations of the Transient Approach

The cyclical quotas which are often characteristic of transient models are an undesireable feature of this approach. The quotas for the peak years of a cycle are often very unrealistic in terms of the number of qualified SEP applicants necessary to support selecting such a large number of officers during a single year. Yet the transient model assumes that all quotas during each year of the planning period are met. If the Marine Corps is unable to meet the projected quotas in any one year, this nullifies the figures for the rest of the planning period

The quota projections of a transient model should not be regarded as precise figures. It is not possible to build into the model all of the conditions which determine actual quota needs. For instance, none of the transient models take into account the fact that an unknown portion of the officers finishing school every year will be due for an unaccompanied overseas tour and, hence, will not be avaiable for immediate utilization in a SEP billet. Moreover, the model is based on a set of assumptions which do not always hold true. For example, all of the transient models assume that all officers will serve in SEP billets during certain years of service established within the model. In reality, however, there are many officers serving in SEP billets with years of service different from those specified in the model.

Therefore, to the extent that the assumptions of the model and the value of its parameters deviate from

reality, the output of the model will deviate from actual quota needs.

b. The Basic Transient Model

The quota cycles which often occur in the basic transient model make it difficult to maintain stable quota figures from year to year. The model's output gives little in the way of clues as to how to best redistribute the quotas to attain a more stable yearly quota figure while minimizing the quota overall. Moreover, the number of applications by officers who desire to participate in SEP may not be sufficient to meet an unusually large quota in a particular period. In other periods when the quota is unusually low, there may be a surplus of qualified applicants who may, or may not, be selected. Also the basic transient model was designed to model an every-other-tour policy, and is not adaptable to modelling other tour policies.

The basic transient model limits the method of applying continuation fractions to two basic approaches. Continuation fractions can be applied yearly to both the inventory (including officers serving in an initial SEP tour) and students. This results in a definite upward estimation of the quotas for most MOS's for the reasons set forth in Chapter V. Conversely, continuation fractions can be applied as cumulative fractions (for some rank or groups of years). This second approach may understate real quota needs because the inventory is not allowed to attrite on a yearly basis. This is shown in the case where a cumulative continuation fraction for the years six through ten is applied in year ten. Under the modelled conditions, officers who would be expected to attrite in year eight would remain in the SEP inventory for two more years before

being attrited. The basic transient model does not allow the flexibility needed to distinguish between officers who can be expected to attrite and officers who are not expected to attrite in a particular year (i.e. officers who are students or who are serving in an initial SEP tour)

c. The Smoothed Transient Model

The smoothed transient model does not minimize the quota, at least in the short run. Aggregate totals over a short period (e.g. five years) may noticeably exceed the quotas given by the basic transient model. However, in the long run the average annual quota should approximate both the annual average quota for the steady state and basic transient models. The smoothed transient model is like the basic transient model as to limitations on flexibility in applying continuation rates. Additionally, the smoothed transient model, like the basic transient model, was designed to model only an every-other-tour policy.

d. The Career Path Transient Model

Other than the general limitations of the transient approach discussed above, this model has no other specific limitations.

IX. COMPARISON OF QUOTAS

Using the base case of each model as discussed in Chapters IV through VII, a comparison of the steady state (SS), career path steady state (CPSS), basic transient (BT), smoothed transient (SMT), and career path transient (CPT) models are presented for MOS's 9620, 9624, 9644, 9646, and 9650 in Figure 17.

The base case for each model incorporates an every-other-tour utilization policy, a three year tour length, a two year delay for graduate school, the billet requirements of Appendix A and the continuation rates of Appendix B. These parameters were selected as a basis of comparison since they most nearly represent current Marine Corps policy regarding SEP and the actual environment in which SEP operates. The data presented in Figure 17 was taken from actual model ouput contained in Appendix D. In order to facilitate the comparison of transient and steady state quotas, the transient quota is presented as an average of the quotas for twenty years.

The average annual quotas for all SEP MOS's considered are consistent for the steady state, basic transient, and smoothed transient models. The career path steady state model is also generally consistent with the three aforementioned models. The slightly lower career path steady state quotas for SEP MOS's 9620 and 9644 appear to be the result of the model's assigning of a relatively large share of the total quota to career path 3. This path has a higher continuation rate for SEP trained officers in the rank of major than the continuation rates for majors in the

other three models.

The higher quota given by the career path transient model occurs because of the difference in the way continuation fractions are applied vis-a-vis the other four models. Both steady state models use a cumulative continuation rate because the models are not time conscious. Cumulative continuation rates were used for the basic transient and smoothed transient models to avoid biasing the models by attriting officers who are in school or in an initial SEP tour. The career path transient model can consider time and can consider when, by year within a career path, a specific yearly continuation fraction may be applied. This allows attrition of officers who have served an initial SEP tour without affecting those officers in the same rank who have not yet completed their initial tour. Billet vacancies, therefore, occur at a rate greater than if vacancies were just the result of normal tour rotation. And, within a rank, attrition can occur after promotion to that rank but before serving a SEP tour. The overall result of the foregoing is larger quotas to meet more billet vacancies and replace officers who leave the system.

The quotas given by the three transient models for year 1 represent student input into SEP for fiscal year (FY) 1978. These FY78 quotas, along with the steady state models' quotas, are furnished in Figure 18.

The disparity in quotas for a given MOS is obvious. The results given by the steady state models are not surprising since these quotas are the same for any period. The quotas given by the three transient models differ considerably in some cases (e.g. SEP MOS 9650). Perusal of the quotas for year 2 and year 3 provided in Appendix D reveals that the disparity of quotas occurs not only among the transient models used in a certain period, but also by individual

models from year to year.

The difference between the quotas given by the basic transient and smoothed transient models is the result of the smoothing function of the smoothed transient model. The difference between the career path transient model and the other two transient models is caused by two factors. First, the method of applying continuation fractions usually results in higher quotas on the average for the career path transient model. Second, the years of service in which a SEP trained officer serves in a SEP tour for a particular rank are not always the same for the three transient models. For example, for the rank of captain an officer would serve in a SEP billet in years seven through nine, if the basic transient or smoothed transient models are used. If the career path transient model is used, the SEP tour is served during years six through eight. For a hypothetical case where there are five SEP billets for the rank of captain, five SEP trained captains all with eight years of service in period (0), and no attrition, there is no requirement for additioanal officers to meet the billet needs of period (0) regardless of the transient model used. But, for period (1) the career path transient model would show a need for five officers to be trained and available to meet the billet requirements. Yet, for the other two transient models, new officer input into the SEP billets is not needed in period (1), and will not be needed until period (2).

SEP MOS	SS	CPSS	BT	SMT	CPT
9620	4	3	4	4	5
9624	9	9	9	9	13
9644	10	8	10	10	13
9648	6	6	6	6	7
9650	11	11	11	11	15

Figure 17. Comparison by Model and by MOS of Twenty Year Average Annual Quotas.

SEP MOS	MC FY78 Goal	SS	CPSS	BT	SMT	CPT
9620	2	4	3	0	2	8
9624	12	9	9	0	6	29
9644	10	10	8	2	2	14
9648	9	6	6	2	5	8
9650	15	11	11	7	13	23

Figure 18. Comparison by Model and by MOS of FY78 Quotas.

X. CONCLUSIONS

The quota projections of the steady state and career path steady state models provide average annual quotas which are useful for long range planning. Although a steady state quota might overstate or understate actual needs in the short run, actual requirements will reach steady state conditions if a steady state quota is used on an annual basis.

The smoothed transient model provides quotas which represent a compromise between the two extremes of a steady state or a transient approach. The projections of the smoothed model are allowed to exceed actual needs in the short run in order to attain a long term stable quota.

All of the five models presented here have incorporated the basic set of conditions such as billet structure, tour length, utilization policy, inventory attrition, etc., which collectively determine the flow of officers through the Special Education Program. Consequently, the projections of all of the models are useful as approximations on which to base actual SEP quotas. Moreover, the design of each model enables the user to consider how changes in billet structure, tour length, attrition, etc. will affect future quotas.

When using these models, the decision maker is advised to keep in mind the various assumptions on which each model is based and the actual calculations used within each model to determine quotas. Quota projections by any of the models should be regarded as only approximations of actual needs

and should be tempered by the decision makers's knowledge of the SEP inventory and any other relevant information.

APPENDIX A

SEP BILLETS FOR SELECTED MOS'S

MOS	Rank	Billets
Aeronautical Engineer (9620)	CAPT	2
	MAJ	8
	LTCOL	7
	COL	3
		20
Electronics Engineer (9624)	CAPT	9
	MAJ	22
	LTCOL	14
	COL	1
		46
Comptroller (9644)	CAPT	0
	MAJ	14
	LTCOL	20
	COL	17
		51
Data Systems Specialist (9646)	CAPT	11
	MAJ	14
	LTCOL	7
	COL	1
		33

MOS	Rank	Billets
Operations Analyst (9650)	CAPT	13
	MAJ	28
	LTCOL	17
	COL	1

APPENDIX B

CONTINUATION FRACTIONS

The continuation fractions listed below are planning factors currently used by the Marine Corps to estimate attrition of commissioned officers (e.g. 87 percent of officers with one year of service will remain in the Marine Corps to have two years of service.). The fractions have been rounded to the nearest one hundreth. These planning factors were obtained from the Manpower Plans and Policy Division (Code MPP), Headquarters U. S. Marine Corps.

Year	Continuation Fraction	Year	Continuation Fraction
0-1	0.98	15-16	0.95
1-2	0.87	16-17	0.95
2-3	0.87	17-18	0.80
3-4	0.89	18-19	0.77
4-5	0.83	19-20	0.73
5-6	0.90	20-21	0.95
6-7	0.92	21-22	0.94
7-8	0.95	22-23	0.94
8-9	0.94	23-24	0.64
9-10	0.85	24-25	0.79
10-11	0.85	25-26	0.73
11-12	0.94	26-27	0.85
12-13	0.94	27-28	0.88
13-14	0.95	28-29	0.09
14-15	0.95		

APPENDIX C

APL FUNCTIONS FOR CAREER PATH MODELS

QUOTA1 is an interactive APL function which has been designed to calculate quotas based on an every-other-tour policy using equations (VI.1) through (VI.10). QUOTA1, shown in Figure A1, is a dyadic function taking scalars for both left and right arguments. The left argument is the last two digits of the SEP MOS and the right argument is the number of years in the planning period. Therefore:

```
50 QUOTA1 20
```

will calculate quotas for SEP MOS 9650 for the next 20 years.

Before use, five global variables must be assigned values by the user:

MOSV = a vector of two-digit numbers corresponding to the last two digits of each SEP MOS. The k^{th} element will be the k^{th} MOS, thus MOSV will have as many elements as there are SEP MOS's. Let this be m.

INV = m x 5 x 30 matrix of current inventories, where INV_{jpi} is the number of officers in path p with MOS j and i years of service.

CR = 5 x 30 matrix of continuation rates where CR_{ip} is the fraction of officers in path p with i years of service who will remain in the Marine Corps to have (i+1) years of service.

BI = m x 4 matrix of billets.

A = the fraction of the major's quota which will be assigned to path 2.

Lines 1-3 of QUOTA1 as shown in Figure A1 select the curent inventory from INV which corresponds to the MOS specified in the left argument of the function. Lines 4 through 7 use (VI.3) to project the inventory into the future in order to calculate the legacies of the current inventory. Lines 8 through 21 calculate the quota using (VI.4). Lines 22 through 28 places the quota in the inventory according to (VI.6) through (VI.10) for the next iteration of the function. Lines 29 and 30 format and print the output. The output is a table with 6 columns. Column 1 gives the year, columns 2 through 5 give the four numbers, and column 6 gives the total annual quota.

QUOTA2 is a function which calculates quotas based on an every-third-tour utilization policy. QUOTA2 is identical to QUOTA1 except for lines 13-15 which reflect the difference of placement of SEP tours within the 5 career paths due to the different SEP utilization policies on which QUOTA1 and QUOTA2 are based.

```
      ∇QUOTA1[⎕]∇
    ∇ MOS QUOTA1 N;I;R;S;T;B;M;P;V;D;E;K
[1]    K←MOSV⍳MOS
[2]    R← 4 5 30 ⍴0
[3]    R[1;;]←INV[K;;]
[4]    I←1
[5]   L1:R[I+1;;]←0, 0 ¯1 ↓R[I;;]×CR
[6]    →(4>I←I+1)⍴L1
[7]    T← 5 30 ⍴R[(DL+2);;]
[8]    M←1
[9]    Q←(N,6)⍴0
[10]   Q[⍳N;1]←⍳N
[11]  L2:S←4⍴0
[12]   S[1]←+/,T[1;6+V←⍳3]
[13]   S[2]←+/,T[1;13+V],,T[2;10+V],,T[3;13+V]
[14]   S[3]←+/,T[1; 21 22],,T[2;17+V],,T[3; 21 22],,T[4;18+V]
[15]   S[4]←+/,T[1;27+V],,T[2;24+V],,T[3;23],,T[3;27+V],,T[4;25+V],,T[5;22+V],,T[1;23]
[16]   B←4⍴BI[K;]
[17]   P←B-S
[18]   D←0⌈P
[19]   E←⌈D
[20]   Q[M; 2 3 4 5]←E
[21]   Q[M;6]←+/,Q[M; 2 3 4 5]
[22]   T[1;7]←(T[1;7]+Q[M;2])
[23]   T[2;11]←(T[2;11]+⌈(Q[M;3]×(A)))
[24]   T[3;14]←(T[3;14]+⌊(Q[M;3]×(1-A)))
[25]   T[4;19]←(T[4;19]+Q[M;4])
[26]   T[5;23]←(T[5;23]+Q[M;5])
[27]   T←0, 0 ¯1 ↓T×CR
[28]   →(N≥M←M+1)⍴L2
[29]   'YEAR    CAPT    MAJ    LTCOL     COL    TOTAL'
[30]   'I3,5BI8' FMT Q
    ∇
```

Figure A1. QUOTA1, an APL Function Based on an Every-Other-Tour Utlization Policy.

```
      ∇QUOTA2[⎕]∇
    ∇ MOS QUOTA2 N;I;R;S;T;B;M;P;D;V;D;K;E
[1]     K←MOSV⍳MOS
[2]     R← 4 5 30 ⍴0
[3]     R[1;;]←INV[K;;]
[4]     I←1
[5]   L1:R[I+1;;]←0, 0 ¯1 ↓R[I;;]×CR
[6]     →(4>I←I+1)⍴L1
[7]     T← 5 30 ⍴R[(DL+2);;]
[8]     M←1
[9]     Q←(N,6)⍴0
[10]    Q[⍳N;1]←⍳N
[11]  L2:S←4⍴0
[12]    S[1]←+/,T[1;6+V←⍳3]
[13]    S[2]←+/,T[2;10+V],,T[3;13+V]
[14]    S[3]←+/,T[1;16+V],,T[2; 21 22],,T[4;18+V]
[15]    S[4]←+/,T[1;26+V],,T[3;23+V],,T[4; 29 30],,T[5;22+V],,T[2;23]
[16]    B←4⍴BI[K;]
[17]    P←B-S
[18]    D←0⌈P
[19]    E←⌈D
[20]    Q[M; 2 3 4 5]←E
[21]    Q[M;6]←+/,Q[M; 2 3 4 5]
[22]    T[1;6]←(T[1;6]+Q[M;2])
[23]    T[2;11]←(T[2;11]+⌈(Q[M;3]×(A)))
[24]    T[3;14]←(T[3;14]+⌊(Q[M;3]×(1-A)))
[25]    T[4;19]←(T[4;19]+Q[M;4])
[26]    T[5;22]←(T[5;22]+Q[M;5])
[27]    T←0, 0 ¯1 ↓T×CR
[28]    →(N≥M←M+1)⍴L2
[29]    'YEAR    CAPT    MAJ    LTCOL     COL    TOTAL'
[30]    'I3,5BI8' FMT Q
    ∇
```

Figure A2. QUOTA2, an APL Function Based on an Every-Third-Tour Utilization Policy.

APPENDIX D

OUTPUT OF TRANSIENT MODELS

20 *QUOTA* 20

YEAR	*GRP*1	*GRP*2	*GRP*3	*GRP*4	*TOTAL*
1					
2		3	1		4
3			2		2
4	1	2			3
5	1	4			5
6		1	2		2
7	1	2			3
8	1	3			4
9		2	1		3
10	1	2	1		3
11	1	3			4
12		2	1		3
13	1	2	1		3
14	1	3			4
15		2	1		3
16	1	2	1		3
17	1	3			4
18		2	1		3
19	1	2	1		3
20	1	3			4

24 *QUOTA* 20

YEAR	*GRP*1	*GRP*2	*GRP*3	*GRP*4	*TOTAL*
1					
2	4	14			18
3	1	2			3
4	3	2	4		9
5	5	11			16
6	1	3			4
7	3				3
8	5	13			18
9	1	3			4
10	3				3
11	5	13			18
12	1	3			4
13	3				3
14	5	13			18
15	1	3			4
16	3				3
17	5	13			18
18	1	3			4
19	3				3
20	5	13			18

44 *QUOTA* 20

YEAR	*GRP*1	*GRP*2	*GRP*3	*GRP*4	*TOTAL*
1				2	2
2		1		2	3
3		5	9	4	18
4		4	4	1	8
5		3			3
6		6	4		10
7		5	4	3	12
8		3	3	5	11
9		6	4	1	11
10		5	4	3	12
11		3	3	5	10
12		6	4	1	11
13		5	4	3	12
14		3	3	5	10
15		6	4	1	11
16		5	4	3	12
17		3	3	5	10
18		6	4	1	11
19		5	4	3	12
20		3	3	5	10

	46 *QUOTA* 20				
YEAR	*GRP*1	*GRP*2	*GRP*3	*GRP*4	*TOTAL*
1	2				2
2	6	1			7
3	1	2			3
4	3				3
5	6	2			8
6	2	5			7
7	3				3
8	6	2			8
9	2	5			7
10	3				3
11	6	2			8
12	2	5			7
13	3				3
14	6	2			8
15	2	5			7
16	3				3
17	6	2			8
18	2	5			7
19	3				3
20	6	2			8

	50 *QUOTA* 20				
YEAR	*GRP*1	*GRP*2	*GRP*3	*GRP*4	*TOTAL*
1		6			7
2	5	4			9
3	2	13			15
4	3	6			9
5	8				8
6	2	14			16
7	3	5			8
8	8	1			9
9	2	14			16
10	3	5			8
11	8	1			9
12	2	14			16
13	3	5			8
14	8	1			9
15	2	14			16
16	3	5			8
17	8	1			9
18	2	14			16
19	3	5			8
20	8	1			9

20 SMQUOTA 20

YEAR	GRP1	GRP2	GRP3	GRP4	TOTAL
1			2		2
2		2			2
3	1	1	2		3
4	1	3	1		4
5	1	2			3
6	1	2	1		3
7	1	2			3
8	1	2	1		3
9	1	2	1		4
10	1	2	1		4
11	1	2	1		4
12	1	2	1		4
13	1	2	1		4
14	1	2	1		4
15	1	2	1		4
16	1	2	1		4
17	1	2	1		4
18	1	2	1		4
19	1	2	1		4
20	1	2	1		4

24 SMQUOTA 20

YEAR	GRP1	GRP2	GRP3	GRP4	TOTAL
1		6			6
2	2	6			8
3	3	6	1		10
4	3	7	4		14
5	3	3			6
6	3	6			9
7	3	6			9
8	3	6			9
9	3	6			9
10	3	6			9
11	3	6			9
12	3	6			9
13	3	6			9
14	3	6			9
15	3	6			9
16	3	6			9
17	3	6			9
18	3	6			9
19	3	6			9
20	3	6			9

44 SMQUOTA 20

YEAR	GRP1	GRP2	GRP3	GRP4	TOTAL
1				2	2
2		3	3	1	8
3		4	6	4	15
4		3	3		7
5		5	2		7
6		5	3	1	9
7		5	3	3	11
8		5	4	3	11
9		5	4	3	11
10		5	4	3	11
11		5	4	3	11
12		5	4	3	11
13		5	4	3	11
14		5	4	3	11
15		5	4	3	11
16		5	4	3	11
17		5	4	3	11
18		5	4	3	11
19		5	4	3	11
20		5	4	3	11

46 SMQUOTA 20

YEAR	GRP1	GRP2	GRP3	GRP4	TOTAL
1	3	2			5
2	4				4
3	3	1			4
4	4	3	1		8
5	4	1			5
6	4	2			6
7	4	2			6
8	4	2			6
9	4	2			6
10	4	2			6
11	4	2			6
12	4	2			6
13	4	2			6
14	4	2			6
15	4	2			6
16	4	2			6
17	4	2			6
18	4	2			6
19	4	2			6
20	4	2			6

50 SMQUOTA 20

YEAR	GRP1	GRP2	GRP3	GRP4	TOTAL
1	1	9	3		13
2	1	8			9
3	4	8			12
4	4	9	1		14
5	4	3			8
6	4	7			11
7	4	7			11
8	4	7			11
9	4	7			11
10	4	7			11
11	4	7			11
12	4	7			11
13	4	7			11
14	4	7			11
15	4	7			11
16	4	7			11
17	4	7			11
18	4	7			11
19	4	7			11
20	4	7			11

20 *QUOTA*1 20

YEAR	CAPT	MAJ	LTCOL	COL	TOTAL
1	2	3	3		8
2			2		2
3		1	1	1	3
4	1	3	3	1	8
5	1	3	2		6
6		1		1	2
7	1	4	4	1	10
8	1	2			3
9		1	1		2
10	1	4	4	1	10
11	1	2			3
12		1		1	2
13	1	4	5		10
14	1	2			3
15		1		2	3
16	1	4	5		10
17	1	2			3
18		1		1	2
19	1	4	5		10
20	1	2			3

24 *QUOTA1* 20

YEAR	*CAPT*	*MAJ*	*LTCOL*	*COL*	*TOTAL*
1	4	16	9		29
2	3				3
3	2				2
4	4	18	6		28
5	3	3	2		8
6	2		4		6
7	4	17	7		28
8	3				3
9	2				2
10	4	17	10		31
11	3				3
12	2				2
13	4	17	9		30
14	3				3
15	2				2
16	4	17	10		31
17	3				3
18	2				2
19	4	17	10		31
20	3				3

44 *QUOTA1* 20

YEAR	*CAPT*	*MAJ*	*LTCOL*	*COL*	*TOTAL*
1			3	11	14
2		1	4		5
3		2	5		7
4		7	6	9	22
5		4	7	2	13
6		3	4	4	11
7		7	5	8	20
8		4	7		11
9		3	3	5	11
10		7	7	6	20
11		4	5		9
12		3	3	5	11
13		7	7	6	20
14		4	5	1	10
15		3	3	4	10
16		7	8	6	21
17		4	4	1	9
18		3	3	5	11
19		7	9	5	21
20		4	3	1	8

46 *QUOTA*1 20

YEAR	CAPT	MAJ	LTCOL	COL	TOTAL
1	4	2	2		8
2	4		1		5
3	2				2
4	5	2	3		10
5	4	4	1		9
6	2	1	1		4
7	5	4	4		13
8	4	3			7
9	2	1			3
10	5	4	3		12
11	4	3			7
12	2	1			3
13	5	4	3		12
14	4	3			7
15	2	1			3
16	5	4	3		12
17	4	3			7
18	2	1			3
19	5	4	3		12
20	4	3			7

50 *QUOTA*1 20

YEAR	CAPT	MAJ	LTCOL	COL	TOTAL
1	6	11	6		23
2	3	8	4		15
3	3	4	2		9
4	7	13	5		25
5	3	7			10
6	3	4	4		11
7	7	12	8		27
8	3	5			8
9	3	4			7
10	7	12	9		28
11	3	5			8
12	3	4			7
13	7	12	8		27
14	3	5			8
15	3	4			7
16	7	12	9		28
17	3	5			8
18	3	4			7
19	7	12	9		28
20	3	5			8

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